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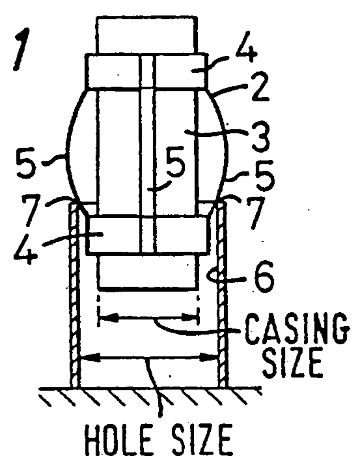
(54) **Spring bow, centralizer and method for its use in a borehole.**

(57) A centralizer for well casing (16) functions in an annular space between the casing (16) and a wellbore (20). It comprises a pair of axially spaced-apart and aligned collars (12) adapted to encircle the well casing and a plurality of spring bows (14) extending between and secured to the collars. Each spring bow (14, 280) has two ends and an outwardly convex curved mid-portion. In a first form of the invention starting force is reduced by providing spring bows having outwardly projecting contact angle reduction members (282) that engage the upper edge of the wellbore (20) as the casing (16) is moved into the wellbore (20) to reduce the effective contact angle of the spring bows (14, 280) with respect to the wellbore (20) and thereby reduce the force required to insert the centralizer (10) into the wellbore (20). In a second form of the invention the spring bows are provided with casing abutment members (283) extending inwardly towards the centralizer's longitudinal axis. The casing abutment members (283) contact the casing (16) as the spring bows (14, 280) are moved towards the casing (16) during insertion of the centralizer (10) into the wellbore (20) to increase the restoring force of the spring bows. The spring bows may have both contact angle reduction members (282) and casing abutment members (283) to give a centralizer having a desirable combination of low starting force with high restoring force.

FIG.1



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SPRING BOW, CENTRALIZER, AND RELATED METHODS

This invention relates to spring bows; to centralizers using such spring bows for maintaining a casing or similar tubular in a central position in a wellbore; and to methods for their use.

Centralizers have long been used in the oil industry for centring well casing in a wellbore, particularly in operations for cementing the casing in the wellbore. The most common conventional centralizers have two collars which are connected by and spaced apart by outwardly directed spring bows which engage and press against the wall of the wellbore.

The American Petroleum Institute's Specification 10D, 3rd Edition, published 17th February 1986, provides a minimum performance standards, test procedures and marking requirements for casing centralizers. It defines various parameters relating to centralizers including the following terms:

starting force;
permanent set;
running force;
flattened;
annular clearance;
standoff;
standoff ratio;
restoring force; and
hole size range.

The definitions of the above terms are incorporated herein by reference. The above specification also contains a table, incorporated herein by reference, relating casing size, minimum restoring force and maximum starting force.

Constructions of centralizers and spring bows are described in US Patent Nos. 2 665 762; 3 124 196; 3 566 965; 3 575 239; 4 143 173; 4 520 869; 4 531 582, in German Patent Application P35 080 868-24, and UK Patent Specification No. 1 110 840 (Austrian Patent No. 2 59484). B & W Incorporated's 1974-1975 catalogue discloses centralizers having spring bows with an arched shape. "Control Formation Sand", Howard Smith Screen Company, 1982, discloses a variety of conventional centralizers. (See page 19). "Primary Cementing Equipment", GEMOCO, 1986 discloses a variety of centralizers and spring bows. Weatherford, "Product Information Cementing Aids GmbH", 1985 discloses a variety of prior art spring bows and centralizers. Weatherford Oil Tool GmbH is a sister company to the Applicants. Weatherford, "1986-87 Products and Services Catalogues", 1985 (primarily pages 22-28) discloses a variety of prior art spring bows and centralizers. Weatherford International, Inc. is the parent company of the Applicants.

Several disadvantages are associated with the use of centralizers with spring bows with large bow heights. As the spring bow is pressed inwardly toward the casing on which the centralizer is placed the force needed to maintain it compressed increases, and a spring with a large bow height needs a comparatively large compressive force to deflect it close to the casing and permit insertion into a wellbore. In starting a centralizer mounted on a casing string, a spring bow of large spring height has to be compressed inwardly a long way because the opening into which the casing is inserted is usually not very much bigger than the casing string itself. The spring bows are therefore subjected to comparatively large compression forces and a corresponding large force or load has to be imposed downwardly upon the casing string. In many instances, with springs having large bow heights, the centralizer cannot be started in the opening merely by the weight of the casing itself on which the centralizer is mounted. Often external weight or forces have to be applied on the casing string. The comparatively large force being exerted by the spring bows on the wall of the opening into which they are inserted creates correspondingly great forces between the spring bows and the surface casing, which must be overcome in lowering the casing string on which centralizer is mounted, and which may create wear on the spring bows.

Generally, the centring force requirement dictates the use of heavy material in the spring bows, a large number of spring bows, and a profile with the spring bows directed outwardly in substantial distance -- and yet the centralizer must be inserted into a wellbore that is relatively small in circumference. A substantial resistance to insertion is encountered due to, inter alia, the force between the spring bows and the tubular or wellbore into which the centralizer is to be inserted.

Restoring force is the force exerted by a centralizer spring bow when the centralizer contacts a restricted inside diameter of a tubular, testpipe, or wellbore. Restoring force is dependent, inter alia, on the extent to which the spring bow has to be compressed upon insertion into the wellbore. A spring bow which is stressed beyond its elastic limit may not have an adequate restoring force.

We have found that the starting force may be reduced and/or the restoring force may be increased by a spring bow for a well casing centralizer that functions in an annular space between a casing and a wellbore, the spring bow comprising a body member having two ends and a mid portion disposed between the two ends and convexly curved away from the two ends, and the mid portion having:

(a) at least one contact angle reduction member extending outwardly beyond the curve of the mid portion of the spring bow for reducing the contact angle between the spring bow and the upper edge of a wellbore into which the centralizer is to be inserted; and/or

(b) at least one casing abutment member extending inwardly inside the curve of the mid portion of the spring bow which, on insertion of the centralizer into the wellbore and on movement of the spring bow towards the casing, contacts the casing to increase the restoring force of the spring bow.

Thus in one form a centralizer provided with the new spring bows has a reduced starting force and in an alternative form it has an increased restoring force. Aspects of each can be combined in a single centralizer whose spring bows provide for increased restoring force and reduced starting force. Starting force is dependent, inter alia, on the "contact angle", of the centralizer spring bows with respect to the inner edge of the bore or tubular into which the centralizer is to be inserted.

One centralizer according to the present invention has collars between which extend spring bows. The spring bows protrude outwardly from the longitudinal axis of the collars. One or more of the spring bows is configured so that the contact angle is reduced for a portion of the spring bow. This configuration is effected by providing a contact angle reduction member on a portion of the spring bow which will contact the inner edge of the bore or tubular into which the centralizer is to be inserted. The contact angle reduction member can be formed and positioned so that its presence does not significantly affect the centralizer's restoring force or has such an effect on it that the advantages with respect to reduced starting force are still desirable.

A spring bow according to the present invention may have one or more contact angle reduction members. A centralizer may only need contact angle reduction members at one end of its spring bows, but a centralizer could be fool-proofed by providing such contact angle reduction members at both ends so that whichever end is inserted will have a reduced starting force. The contact angle reduction members can be formed integrally of the spring bows or they can be separate pieces secured to the spring bows.

A spring bow according to the present invention may have one or more casing abutment members on at least one end of the spring bow for contacting the casing (or other tubular) after the spring bow has moved inwardly on the casing upon insertion into the wellbore. The casing abutment member inhibits movement of the spring bow (or part of the spring bow), toward the casing thereby preventing further reduction in restoring force. A spring bow may need casing abutment members at only one of its ends, but a centralizer spring bow according to this invention may have such members at each of its ends. The casing abutment members can be formed integrally of the spring bows or they can be separate pieces secured to the spring bows. As explained above, a single spring bow can have both one or more contact angle reduction members and one or more casing abutment members.

The contact angle reduction member or the casing abutment member may be pressed or stamped out of the spring bow itself. A centralizer having at least preferred embodiments of the new spring bows of the invention can be made to meet or exceed the American Petroleum Institute's specifications for restoring force and/or starting force of casing centralizers and in a particularly preferred form can satisfy the long-felt need for a centralizer with reduced starting force combined with acceptable or increased restoring force.

For a better understanding of the invention reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1 is a cross-sectional view of a prior art centralizer disposed on casing and partially emplaced within a borehole;

Fig. 1a is an enlargement of a portion of Fig. 1 showing an angle Alpha 1 between the centralizer spring bow and the hole wall;

Fig. 2 is a cross-sectional view of a centralizer according to the present invention disposed on casing and partially emplaced in a borehole;

Fig. 2a is an enlargement of a portion of Fig. 2 showing an angle Alpha 2 between the centralizer spring bow and the hole wall;

Fig. 3 is a view of the centralizer of Fig. 2 after it has entered into the borehole a distance equal to the distance which the centralizer of Fig. 1 has proceeded into the borehole;

Fig. 3a is an enlargement of a portion of Fig. 3 showing an angle Alpha 3 between the centralizer spring bow and the hole wall;

Figs. 4-8 are perspective views of various forms of spring bow according to the present invention;

Figs. 9 and 10 are perspective views of spring bows according to the invention which have casing abutment members;

Figs. 11 and 12 are perspective views of spring bows according to the present invention with both a contact angle reduction member and a casing abutment member;

Figs. 13-16 present test data. Fig. 13 presents data for a prior art device. Figs. 14-16 present data for apparatus according to the present invention having a contact angle reduction member. Figs. 13a, 14a, 15a and 16a show a centralizer spring bow, side view, corresponding to a spring bow tested for the data obtained which is presented in Figs. 13, 14, 15 and 16 respectively;

Figs. 17-20 present graphically the data of Tables 1 and 2 (below). Fig. 17 corresponds to Table I. "STC" data; Fig. 18 to Table II "STC" data; Fig. 19 to Table I "CC" data; and Fig. 20 to Table II "CC" data; and

Figs. 21 and 22 are perspective views of spring bows according to the present invention having a compound contact angle reduction member and casing abutment member.

As shown in Fig. 1 a conventional prior art centralizer 2 disposed about a casing 3 has two end collars 4 spaced apart by a plurality of spring bows 5 connected to the collars 4. The centralizer 2 and casing 3 have been partially inserted into a test pipe or wellbore 6. Bows 5 of the centralizer 2 have contacted the upper edge 7 of the test pipe or wellbore 6 with which they make angle Alpha 1.

A centralizer 10 according to the present invention is shown in Figs. 2 and 3. The centralizer 10 has two end collars 12 to which and between which are secured a plurality of spring bows 14. The centralizer 10 is disposed about a casing 16. The spring bows 14 have secured thereto a contact angle reduction member 18. The casing 16 and centralizer 10 have been partially inserted into a borehole 20. The illustration of Fig. 3 shows the further progression of the casing 16 and centralizer 10 into the borehole 20 and the further movement of the contact angle reduction member on the upper edge 22 of the borehole 20. The difference in contact angle for the prior art centralizer 2 and the centralizer 10 according to the invention is shown in Figs. 1a, 2a and 3a which correspond to the apparatus of Figs. 1, 2 and 3, respectively. The contact angle Alpha 1 of spring bow 5 of centralizer 2 with respect to the upper edge 7 (Fig. 1a) is greater than the contact angle Alpha 2 of the spring bow 14 of the centralizer 10 with respect to the upper edge 22 (Fig. 2a). A portion of the spring bow 14 (Fig. 2a) corresponding to the surface of the contact angle reduction member in contact with the wall of the wellbore 6 has a smaller contact angle than it would if the member 18 were absent. The contact angle Alpha 3 shown in Fig. 3a is relatively small. The contact angle Alpha 3 is for a centralizer 10 which has been inserted the same distance into the hole as the centralizer 2 of Fig. 1. The contact angle reduction member 18 (Figs. 2, 3) contacts the upper edge 22 of the hole sooner than the spring bows 5 of the device of Fig. 1.

Figs. 4-8 illustrate various forms of centralizer spring bows according to the present invention.

A spring bow 40 shown in Fig. 4 has a contact angle reduction member 42 produced by attaching a separate piece to the spring bow 40. Conventional epoxy resin glues serve to secure the contact angle reduction member 42 to the spring bow 40.

A spring bow 50 shown in Fig. 5 has a contact angle reduction member 52 produced by stamping the spring bow with a cutting/forming die or with a separate cutting die and separate forming die. This could be done during the spring bow shaping process. The contact angle reduction member 52 is stamped so that it is connected to the body of the spring bow 50 only along line 54 and the end 56 has been turned inwardly to ensure that the spring bow 50 is insertable into an opening and does not act as a stop member against the upper edge of a wellbore. The contact angle reduction member 52 could be disconnected along line 54 and connected at its other end to the spring bow 50.

A spring bow 60 shown in Fig. 6 has a contact angle reduction member 62 which was originally part of the spring bow, but which has been pressed out of the spring bow 60.

The contact angle reduction members themselves can be formed of any suitable rigid material, including but not limited to: metals, plastics, elastomers, or composite materials.

A spring bow 70 as shown in Fig. 7 is a single integral piece which is made, formed, cast, or stamped to have a contact angle reduction member 72 formed integrally thereof.

A spring bow 80 shown in Fig. 8 has a contact angle reduction member 82 at each of its ends so that whichever end encounters the upper edge of a wellbore, the contact angle is reduced.

The spring bows 90 and 100 of Figs. 9 and 10 respectively, each have a casing abutment member 93, 103 for contacting the tubular casing on which a centralizer with the spring bow has been placed. Casing abutment member 93 is formed by the process used to produce contact angle reduction member 52 of spring bow 50, and is connected to spring bow 90 along line 94 and disconnected at its other end 95. Initially upon compression of the spring bow 90 in the wellbore, the casing abutment member 93 will move with the spring bow 90 and not affect the spring bow movement. Eventually the casing abutment member

93 will contact the surface of the casing and will resist further radially inward movement of the spring bow 90. This increases the restoring force exerted by the spring bow because of reduction of free spring bow length as well as active spring bow height. The spring bow 100 (Fig. 10) has a casing abutment member 103 which is connected along line 105 to the spring bow body but is separated therefrom at line 104.

Figs. 11 and 12 illustrate spring bows with both contact angle reduction members and casing abutment members.

The spring bow 110 shown in Fig. 11 has a pair of symmetrically located contact angle reduction members 112 (similar to contact angle reduction member 62 of spring bow 60) and a single casing abutment member 113 (similar to casing abutment member 93 of spring bow 90).

The spring bow 120 shown in Fig. 12 has a contact angle reduction member 122 (similar to contact angle reduction member 42 of spring bow 40) and a casing abutment member 123 which is a solid separate piece glued to the spring bow 120.

Spring spring bows according to the invention have been made up into well casing centralizers and tested according to American Petroleum Institute Specification 10D, 3rd Edition, pages 7-11.

Fig. 13 presents data regarding starting force for a prior art spring bow such as a spring bow 170 as shown in Fig. 17a. The horizontal axis labelled "MM" shows increasing movement in millimetres of a centralizer with a spring bow 170 into a test pipe. The vertical axis has two labels. The "%" column indicates percentage of API allowable maximum starting force. The vertical column labelled "KN" indicates starting force in kilo-newtons. The test method used was a conventional "over stop collar" method and the centralizer tested with spring bows 170 was a prior art Weatherford ST-III-S centralizer (as described in "Product Information Cementing Aids GmbH"). As shown in Fig. 13 the starting force for the prior art centralizer had a maximum of about 72% of the API allowable after about 27 millimetres of insertion into the test pipe.

Centralizers according to the present invention were tested with spring bows 180, 190, 200 according to the present invention. (See Figs. 14a, 15a, 16a respectively). Each spring bow 180, 190, 200 had a separate contact angle reduction member 182, 192, 202 respectively secured thereto with commercially available epoxy glue. As shown in the graphics of Figs. 14, 15 and 16 the different geometry of the contact-angle reduction members 182, 192, 202 produced different results, but the maximum starting force for each centralizer was reduced as compared to the centralizer tested with spring bows 170.

For the prior art device of Fig. 13 the starting force was about 7.3 KN or about 1640 lbs. The corresponding data for the devices of Figs. 14a, 15a and 16a is as follows:

14a	6.220 KN
15a	6.224 KN
16a	5.872 KN

Height measurement "a" for contact angle reduction member 182 was about 12 mm and length measurement "b" was about 49 mm. Contact angle member 192's height was about 6 mm and length was about 80 mm. Contact angle member 202's height was about 12 mm and length was about 80 mm.

After tests were run on the spring bows of Figs. 14-20 the existing dies were changed to produce contact angle reduction members with more rounded ends for contacting the edge of a hole (or testpipe) by pressing a rounded ridge with its height decreasing toward the apex of the spring bow.

Table I presents test data for the prior art centralizer (ST-III-S) having six spring bows. In Tables 1 and 2 the following terms have the following meanings:

STC: "over stop collar" test data.
CC: "casing collar" test data.
HARDNESS: Rockwell Hardness.
ST.F. N x 100: Starting Force in Newtons Multiplied by 100.
N.F. N x 100: Moving Force in Newtons multiplied by 100
(= Running Force per API definition).
M.F., % of ST.F.: Moving Force as a percentage of starting force.
% of API: Clearance.
N x 100: Newtons multiplied by 100.
R.F. @ 67% of ST.O.: Restoring Force at 67% Standoff
(= 67% Annulus)
ST.O. @ API
min. R.F.: Standoff at API specified minimum Restoring Force.
% of ANN: Percent of annulus or standoff.
MM: Millimetres of standoff.

Table II presents test data for a centralizer according to the present invention which was made by securing contact angle reduction members to the spring bows of the prior art ST-III-S centralizer whose test results are reported in Table I.

Figs. 17-20 give a graphical illustration of the tabulated data of Tables I and II. They show the respective starting and moving forces as horizontal lines, scaled as percentages of API maximum allowable starting force and/or minimum required restoring force. A vertical line (dash-dot) represents the 100% API load for both starting and restoring force. Restoring force is shown as a group of curves with the Y-axis being scaled in percentages of the theoretical ideal annular space (12.25 - 9.625)/2. The so-called API restoring point is marked at 100% and 67% of this ideal annulus.

Fig. 17 shows graphically the data for the prior art centralizer's "over stop collar" test from Table I ("STC" data).

Fig. 19 shows graphically the data for the prior art centralizer's "over casing collar" tests from Table I ("CC" data). The square symbol in Fig. 17 indicates the graph lines (dashed and dark) corresponding to the data for tests 06 of Table I. The plus symbol corresponds to tests 07 of Table I and the diamond symbol corresponds to tests 09 of Table I. Similarly for Fig. 19 the square symbol corresponds to tests 03; the plus symbol to tests 04; and the diamond symbol to tests 05 -- all of Table I.

In general terms these graphs show the annular clearance which the centralizer provides under different loads (restoring force). The horizontal dark full lines in the lower left corner of the graphs (Figs. 23-26) show starting force and the dashed lines show moving force of the respective centralizers.

Similarly, Figs. 18 and 20 present data for centralizers according to the present invention. Fig. 18 presents the "over stop collar" data and Fig. 20 presents the "over casing collar" data. In Figs. 18 and 20 the symbols on the graphs correspond to the tests 19, 20, 21, 2, 3, 4, 5, 6 and 7 of Table II as indicated.

Tests were performed with centralizers installed over stop collars and over casing collars because both installations are common in drilling operations. As can be seen in Table I, the centralizer with spring bows without contact angle reduction members showed starting forces (ST.F.) of between 5.97 KN and 7.65 KN or between 83.88% and 107.9% of API allowable, respectively, for installation over stop collars. Table II shows the starting force for the same type spring bows, but with contact angle reduction members according to the present invention, between 4.88 KN and 5.75 KN or between 68.57% and 80.79% of API allowable for this type installation. The resulting reduction is therefore between 18% and 25% for installation over stop collar.

For installation over casing collar, Table I shows starting forces for the prior art devices to be between 9.45 KN and 9.63 KN or 132.78% and 135.31% of API allowable, while spring bows with contact angle reduction members, as taught by the present invention of Table II, show it to be between 6.62 KN and 7.55 KN or between 93.02% and 106.08% of API allowable. In this case the reduction achieved by use of spring bows according to this invention is between 30% and 22%. Discounting the case of 7.55 KN which is considered to be a testing anomaly, the reduction achieved is between 30% and 26%.

Figs. 21 and 22 illustrate spring bows according to the present invention which have both a contact angle reduction member and a casing abutment member.

The spring bow 270 shown in Fig. 21 has a compound member 277 which includes both a contact angle reduction member 272 and a casing abutment member 273 formed integrally thereof.

The spring bow 280 shown in Fig. 28 has a contact angle reduction member 282 connected at one end to the body of the spring bow 280. The spring bow 280 also has a casing abutment member 283 connected at one end to the body of the spring bow 280. Of course either of the members 282 and 283 could be used alone on a spring bow.

TABLE I

HARDNESS		STC 06 43		STC 07 43		STC 09 43		CC 03 43		CC 04 43		CC 05 43	
ST.F	Nx100	597	83.88%	765	107.48%	655	92.03%	955	134.19%	963	135.31%	945	132.78%
N.F.	Nx100	371	52.13%	313	43.98%	401	56.34%	396	55.64%	405	56.91%	412	57.89%
M.F.,%	of ST.		62.14%		40.92%		61.22%		41.47%		42.06%		43.60%
Nx100	% of API	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN
0	0%												
50	7%												
100	14%												
150	21%												
200	28%	29.83	89.46%	28.90	86.69%								
250	35%					28.74	86.21%	29.75	89.24%	30.55	91.64%	30.61	91.87%
300	42%			28.83	86.48%	28.55	85.64%	29.64	88.91%	30.43	91.28%	30.44	91.31%
350	49%	29.65	88.94%	28.60	85.79%	28.32	84.95%	29.51	88.52%	30.29	90.86%	30.25	90.74%
400	56%	29.27	87.80%	28.29	84.86%	28.00	83.99%	29.35	88.04%	30.15	90.44%	30.05	90.14%
450	63%	28.87	86.60%	27.92	83.75%	27.49	82.46%	29.19	87.56%	30.02	90.05%	29.84	89.51%
500	70%	28.40	85.19%	27.45	82.34%	27.02	81.05%	29.03	87.08%	29.82	89.45%	29.56	88.67%
550	77%	27.93	83.78%	26.98	80.93%	26.56	79.67%	28.84	86.51%	29.62	88.85%	29.25	87.74%
600	84%	27.44	82.31%	26.51	79.52%	26.02	78.05%	28.60	85.79%	29.37	88.10%	28.83	86.48%
650	91%	26.90	80.69%	26.01	78.02%	25.51	76.52%	28.34	85.01%	29.09	87.26%	28.37	85.10%
700	98%	26.32	78.95%	25.46	76.37%	24.98	74.93%	28.03	84.08%	28.77	86.30%	27.90	83.69%
750	105%	25.71	77.12%	24.87	74.60%	24.49	73.46%	27.72	83.15%	28.43	85.28%	27.45	82.34%
800	112%	25.08	75.23%	24.26	72.77%	23.95	71.84%	27.40	82.19%	28.05	84.14%	27.03	81.08%
850	119%	24.50	73.49%	23.73	71.18%	23.33	69.88%	27.02	81.05%	27.67	83.00%	26.60	79.79%
900	126%	23.97	71.90%	23.19	69.56%	22.72	68.15%	26.60	79.79%	27.28	81.83%	26.12	78.35%
950	133%	23.44	70.31%	22.64	67.91%	22.14	66.41%	26.18	78.53%	26.90	80.69%	25.67	77.00%
1000	141%	22.92	68.75%	22.14	66.41%	21.55	64.64%	25.76	77.27%	26.55	79.64%	25.25	75.74%
1050	148%	22.45	67.34%	21.66	64.97%	21.04	63.11%	25.35	76.04%	26.18	78.53%	24.85	74.58%
1100	155%	22.01	66.02%	21.24	63.71%	20.52	61.55%	24.96	74.87%	25.76	77.27%	24.46	73.37%
1150	162%	21.57	64.70%	20.93	62.78%	20.43	61.28%	24.58	73.73%	25.36	76.07%	24.06	72.17%
1200	169%	21.14	63.41%	20.73	62.18%			24.19	72.56%	24.98	74.93%	23.66	70.97%
1250	176%			20.37	61.10%			23.80	71.39%	24.61	73.82%	23.29	69.86%
1300	183%			19.95	59.84%			23.42	70.25%	24.25	72.74%	22.97	68.90%
1350	190%	20.30	60.89%	19.53	58.58%			23.05	69.14%	23.92	71.75%	22.67	68.00%
1400	197%							22.69	68.06%	23.64	70.91%	22.38	67.13%
1450	204%	21.14	60.41%					22.33	66.98%	23.37	70.10%	22.08	66.23%
1500	211%							21.97	65.90%	23.12	69.35%	21.83	65.48%
1550	218%							21.63	64.88%	22.87	68.60%	21.60	64.79%
1600	225%							21.54	64.61%	22.59	67.76%	21.37	64.10%
R.F.@ 67%	ST.O.		146%		137%		130%		202%		232%		196%
ST.O.@ AP	min R.F.		76%		76%		74%		84%		86%		83%

TABLE II

		STC		STC		STC		CC		CC		CC		CC		CC		CC	
		19		20		21		2		3		4		5		6		7	
HARDNESS		44		44		44		44		43		43		44		43		43	
ST.F.	Nx100	488	68.57%	503	70.68%	575	80.79%	681	95.69%	662	93.02%	755	106.08%	710	99.76%	687	96.53%	678	95.26%
N.F.	Nx100	271	38.08%	271	38.08%	316	44.40%	305	42.86%	298	41.87%	303	42.57%	292	41.03%	295	41.45%	289	40.61%
M.F.,% of ST.F			55.53		53.88%		54.96%		44.79%		45.02%		40.13%		41.13%		42.94%		42.63%
Nx100	% of API	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of ANN	mm	% of AN
0	0%																		
50	7%																		
100	14%																		
150	21%																		
200	28%	30.04	90.11%	29.25	87.74%	29.71	89.12%					30.32	90.95%	27.33	81.98%	30.05	90.14%	27.89	83.66%
250	35%	29.96	89.87%	29.18	87.53%	29.60	88.79%	29.16	87.47%	29.01	87.02%	30.23	90.68%	26.83	80.48%	29.51	88.52%	27.81	83.42%
300	42%	29.78	89.33%	29.09	87.26%	29.45	88.34%	28.99	86.96%	28.81	86.42%	30.07	90.20%	26.71	80.12%	29.40	88.19%	27.70	83.09%
350	49%	29.54	88.61%	28.94	86.81%	29.19	87.56%	28.74	86.21%	28.58	85.73%	29.86	89.57%	26.53	79.58%	29.24	87.71%	27.56	82.67%
400	56%	29.27	87.80%	28.79	76.36%	28.90	86.69%	28.43	85.28%	28.25	84.74%	29.62	88.85%	26.33	78.98%	28.98	86.93%	27.37	82.10%
450	63%	28.99	86.96%	28.48	85.43%	28.51	85.52%	28.11	84.32%	27.85	83.54%	29.35	88.04%	26.09	78.26%	28.69	86.06%	27.15	81.44%
500	70%	28.65	85.94%	28.14	81.41%	28.12	84.35%	27.71	83.12%	27.43	82.28%	29.07	87.20%	25.80	77.39%	28.39	85.16%	26.82	80.45%
550	77%	28.26	84.77%	27.75	83.24%	27.71	83.12%	27.28	81.83%	27.01	81.02%	28.74	86.21%	25.48	76.43%	28.08	84.23%	26.49	79.46%
600	84%			27.34	82.01%	27.30	81.89%	26.86	80.57%	26.58	79.73%	28.41	85.22%	25.13	75.38%	27.75	83.24%	26.13	78.38%
650	91%	27.33	81.98%	26.92	80.75%	26.88	80.63%	26.42	79.25%	26.14	78.41%	28.05	84.14%	24.79	74.36%	27.40	82.19%	25.75	77.24%
700	98%	26.86	80.57%	26.50	78.20%	26.45	79.34%	25.97	77.90%	25.71	77.12%	27.70	83.09%	24.44	73.31%	27.04	81.11%	25.37	76.10%
750	105%	26.40	79.19%	26.07	79.49%	26.03	78.08%	25.51	76.57%	25.26	75.77%	27.36	82.07%	24.09	72.26%	26.69	80.06%	24.98	74.93%
800	112%	25.92	77.75%	25.64	76.91%	25.58	76.73%	25.06	75.17%	24.82	74.45%	27.01	81.02%	23.74	71.21%	26.32	78.95%	24.60	73.79%
850	119%	25.42	76.25%	25.21	75.62%	25.12	75.35%	24.60	73.79%	24.38	73.13%	26.65	79.94%	23.38	70.13%	25.96	77.87%	24.20	72.59%
900	126%	24.92	74.75%	24.79	74.36%	24.65	73.94%	24.11	72.32%	23.94	71.81%	26.30	78.89%	23.01	69.02%	25.60	76.79%	23.82	71.45%
950	133%	24.40	73.19%	24.37	73.10%	24.19	72.56%	23.63	70.88%	23.52	70.55%	25.94	77.81%	22.65	67.94%	25.24	75.71%	23.43	70.28%
1000	141%	23.87	71.60%	23.95	71.84%	23.73	71.18%	23.14	69.41%	23.10	69.29%	25.58	76.73%	22.30	66.89%	24.89	74.66%	23.06	69.17%
1050	148%	23.34	70.01%	23.54	70.61%	23.29	69.86%	22.66	67.97%	22.72	68.15%	25.22	75.65%	21.95	65.84%	24.55	73.64%	22.69	68.06%
1100	155%	22.82	68.45%	23.13	69.38%	22.85	68.54%	22.18	66.53%	22.40	67.19%	24.87	74.60%	21.59	64.76%	24.21	72.62%	22.32	66.95%
1150	162%	22.30	66.89%	22.75	68.24%	22.41	67.22%	21.71	65.12%	22.09	66.26%	24.52	73.55%	21.26	63.77%	23.87	71.60%	21.95	65.84%
1200	169%	21.80	65.39%	22.36	67.07%	22.00	65.99%	21.23	63.68%	21.77	65.30%	24.18	72.53%	20.94	62.81%	23.54	70.61%	21.59	64.76%
1250	176%	21.32	63.95%	21.99	65.96%	21.59	64.76%	20.78	69.33%	21.46	64.37%	23.85	71.54%	20.64	61.91%	23.21	69.62%	21.23	63.68%
1300	183%	20.81	62.42%	21.67	65.00%	21.20	63.59%	20.38	61.18%	21.15	63.44%	23.54	70.61%	20.35	61.04%	22.91	68.72%	20.89	62.66%
1350	190%	20.49	61.46%	21.35	64.04%	20.81	62.42%	20.01	60.01%	20.87	62.60%	23.28	69.83%	20.07	60.20%	22.61	67.82%	20.55	61.64%
1400	197%			21.04	63.11%	20.46	61.37%	19.65	58.94%	20.58	61.73%	23.00	68.99%	19.80	59.39%	22.32	66.95%	20.23	60.68%
1450	204%	20.07	60.20%	21.01	63.02%	20.44	61.31%	19.29	57.86%	20.29	60.86%	22.71	68.12%	19.55	58.64%	22.05	66.14%	19.95	59.84%
1500	211%	19.66	58.97%	20.68	62.03%	20.09	60.26%	18.97	56.90%	20.05	60.14%	22.45	67.34%	19.32	57.95%	21.77	65.30%	19.75	59.24%
1550	218%	19.27	57.80%	20.36	61.07%			18.69	56.06%	19.84	59.51%	22.20	66.59%	19.10	57.29%	21.54	64.61%	19.55	58.64%
1600	225%			20.03	60.08%	20.06	60.17%	18.55	55.64%	19.65	58.94%	21.99	65.96%	18.92	56.75%	21.30	63.89%	19.34	58.01%
R.F.@ 67%	ST.O.		160%		169%		162%		151%		150%		207%		138%		185%		153%
ST.O.@ AP min R.F.			80%		78%		79%		77%		76%		83%		73%		81%		75%

Claims

1. A spring bow (14, 40, 50, 60, 70, 80, 90, 100, 110, 120, 270, 280) for a well casing centralizer that functions in an annular space between a casing and a wellbore (20), the spring bow comprising a body member having two ends and a mid portion disposed between the two ends and convexly curved away from the two ends, characterized in that the mid portion is provided with:

(a) at least one contact angle reduction member (18, 42, 52, 62, 72, 82, 112, 122, 272, 282) extending outwardly beyond the curve of the mid portion of the spring bow for reducing the contact angle between the spring bow and the upper edge of a wellbore (20) into which the centralizer is to be inserted; and/or

(b) at least one casing abutment member (93, 103, 113, 123, 273, 283) extending inwardly inside the curve of the mid portion of the spring bow which, on insertion of the centralizer (10) into the wellbore and on movement of the spring bow towards the casing (16) contacts the casing (16), to increase the restoring force of the spring bow.

2. A spring bow according to Claim 1, characterized in that the or each contact angle reduction member (52, 62, 72, 82) or casing abutment member (93, 103, 113, 273, 283) is formed integrally with the spring bow.

3. A spring bow according to Claim 1, characterized in that the or each contact angle reduction member (18) or casing abutment member (123) is a separate piece secured to the spring bow.

4. A spring bow according to Claim 1, 2 or 3, characterized in that is comprises a contact angle reduction member (82, 112) located adjacent each end of the spring bow.

5. A spring bow according to any preceding Claim, characterized in that it comprises a casing abutment member located adjacent each end of the spring bow.

6. A spring bow according to any preceding Claim, characterized in that the contact angle reduction member(s) (52), when viewed in profile, comprise ridge portions angled away from the mid portion of the spring bow and terminating in rounded ends (56).

7. A centralizer for well casing comprising a pair of axially spaced apart and aligned collar means (12) and a plurality of spring bows (14) extending between and secured to the collar means (12), characterized in that said spring bows (14) are as claimed in any of Claims 1 to 6.

8. A method for employing casing in a wellbore, characterized in that it comprises the steps of disposing a centralizer (10) as claimed in Claim 7 on a casing (16), inserting the casing (16) into the top of the wellbore (20) and moving the casing (16) so that it is contained within the wellbore (20).

9. A method according to Claim 8, wherein:

a) the spring bows form a contact angle with the wellbore upon insertion of the centralizer into the wellbore; and

b) the spring bows exert a restoring force on placement of the centralizer on the casing within the wellbore; characterized in that

c) the spring bows have contact angle reduction members that reduce the contact angle of the spring bows with respect to the wellbore and thereby reduce the force required to insert the centralizer into the wellbore.

10. A method according to Claim 8 or 9, characterized in that the spring bows have casing abutment members that upon insertion of the centralizer into the wellbore contact the casing and increase the restoring force of the spring bows.

FIG.1

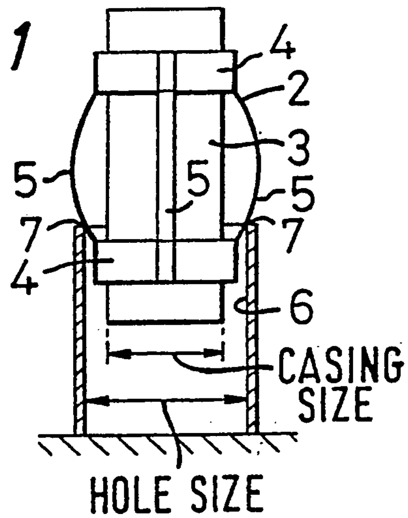


FIG.1a

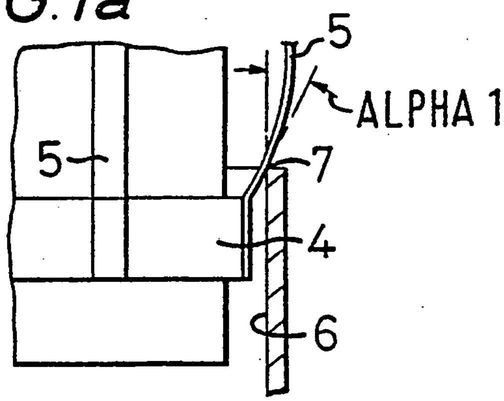


FIG.2

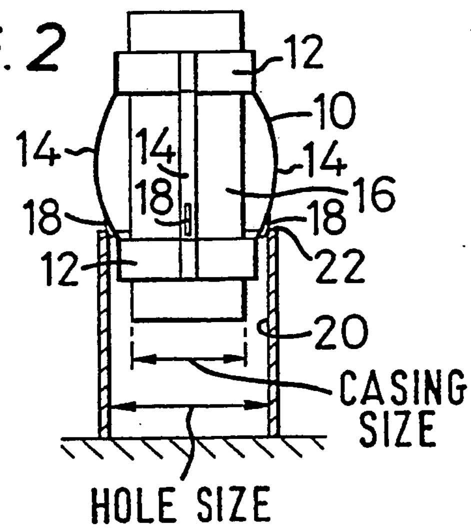


FIG.2a

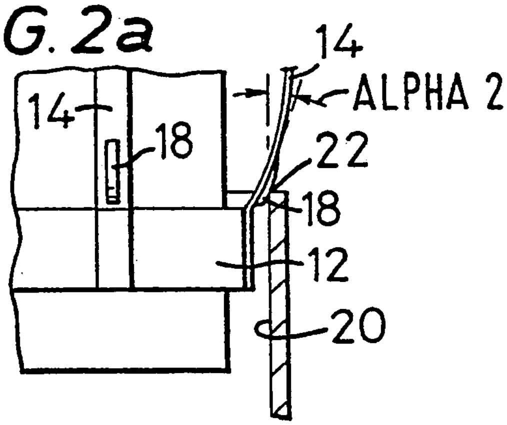


FIG.3

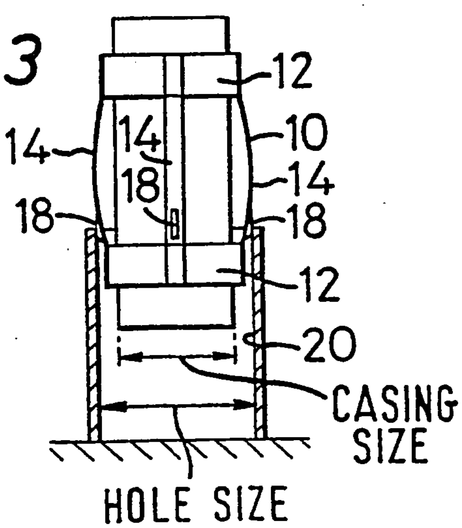


FIG.3a

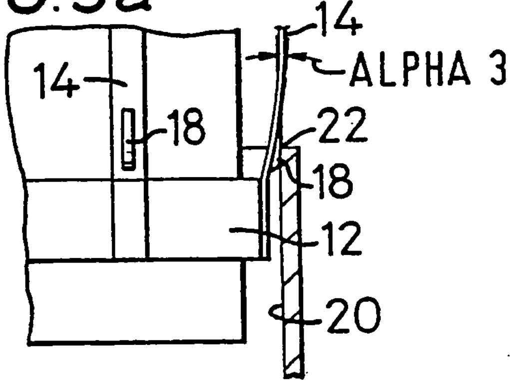


FIG. 4

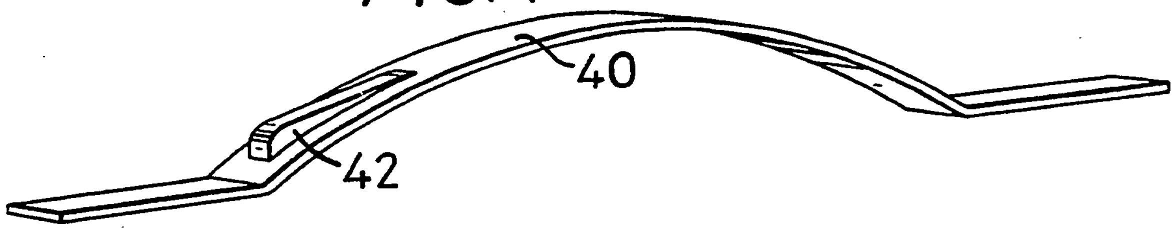


FIG. 5

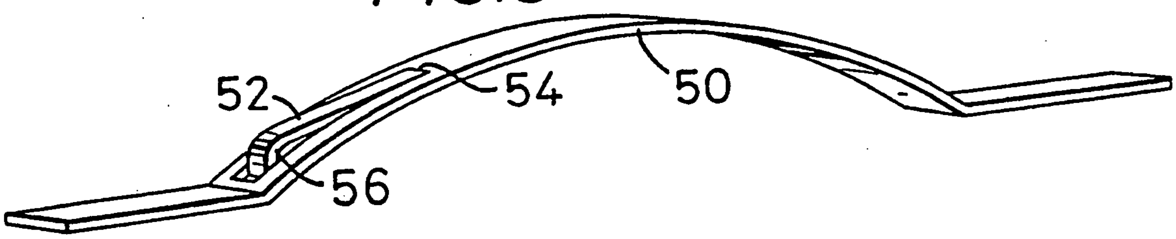


FIG. 6

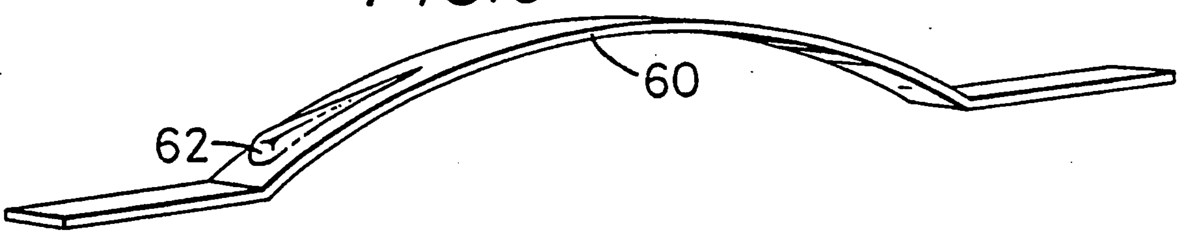


FIG. 7

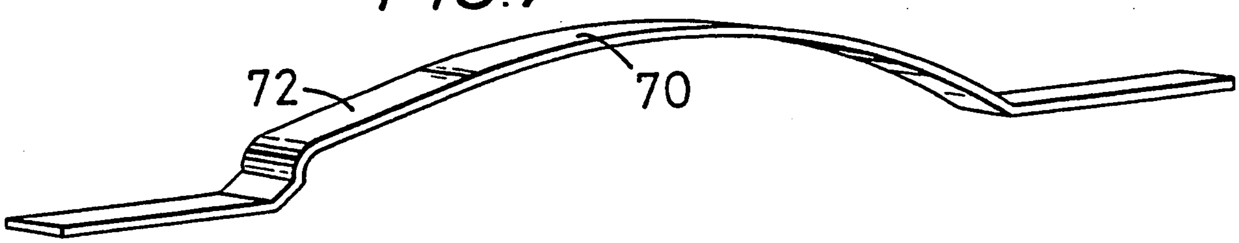


FIG. 8

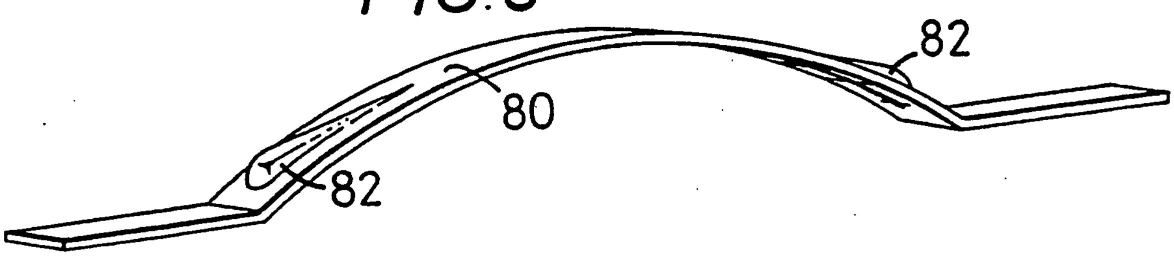


FIG.9

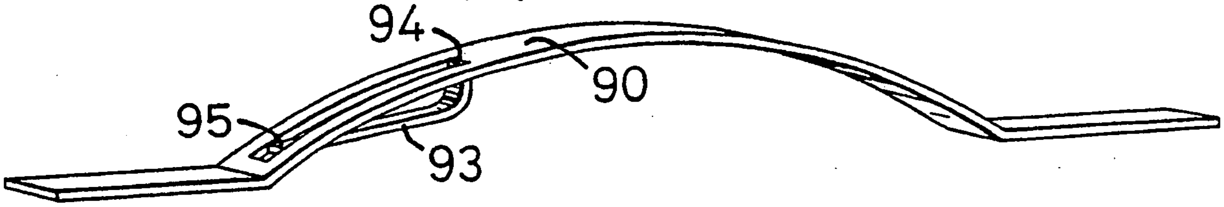


FIG.10

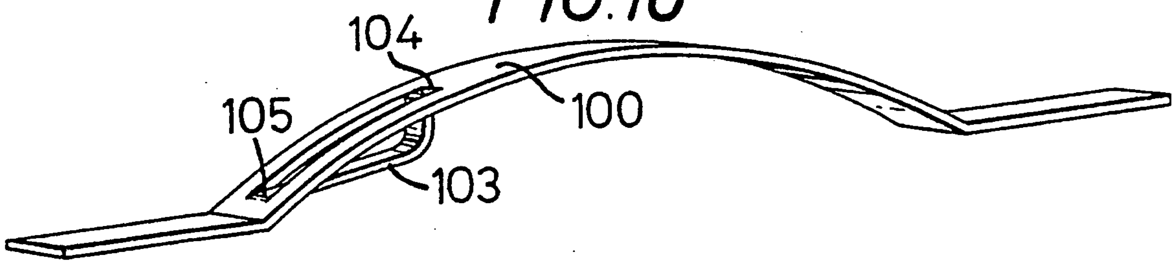


FIG.11

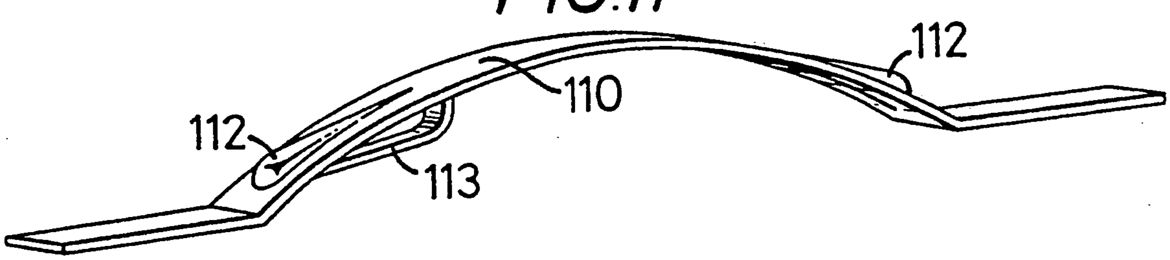
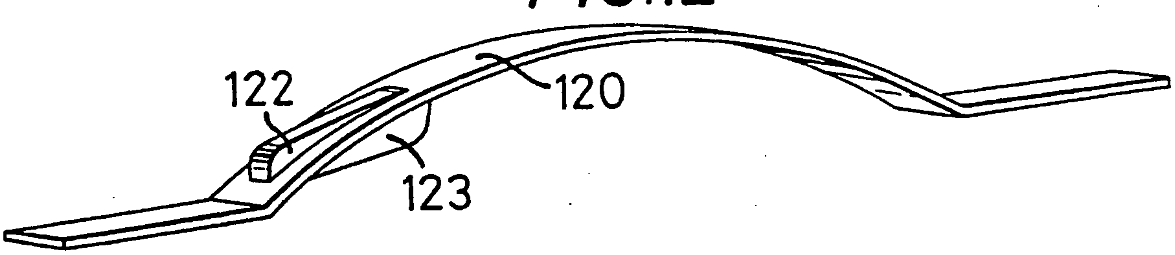


FIG.12



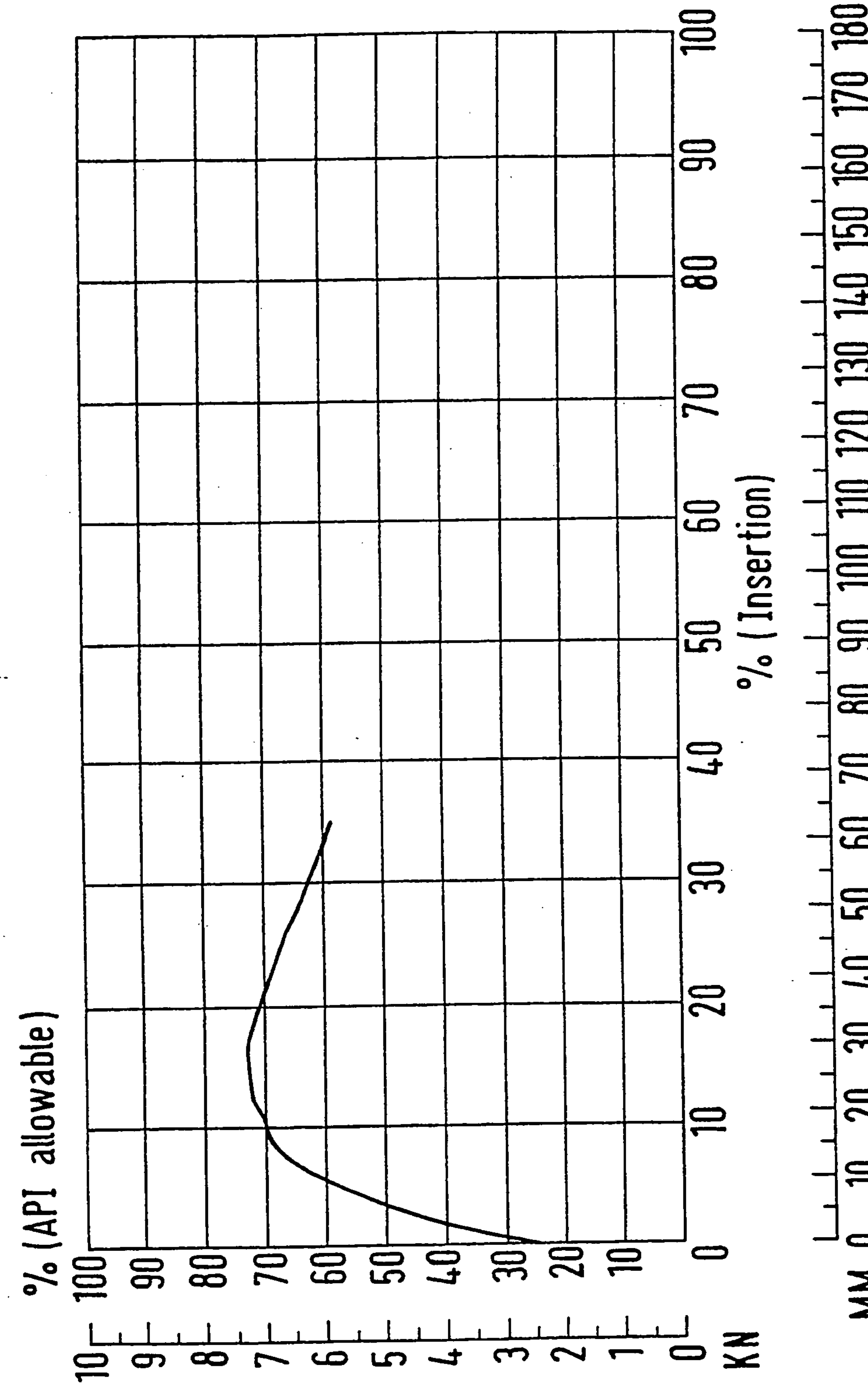


FIG.13

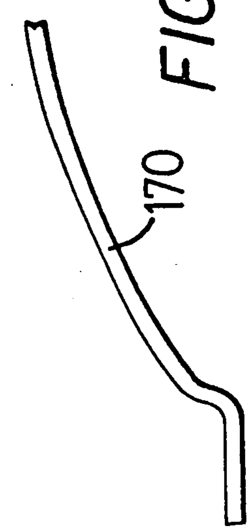


FIG.13a

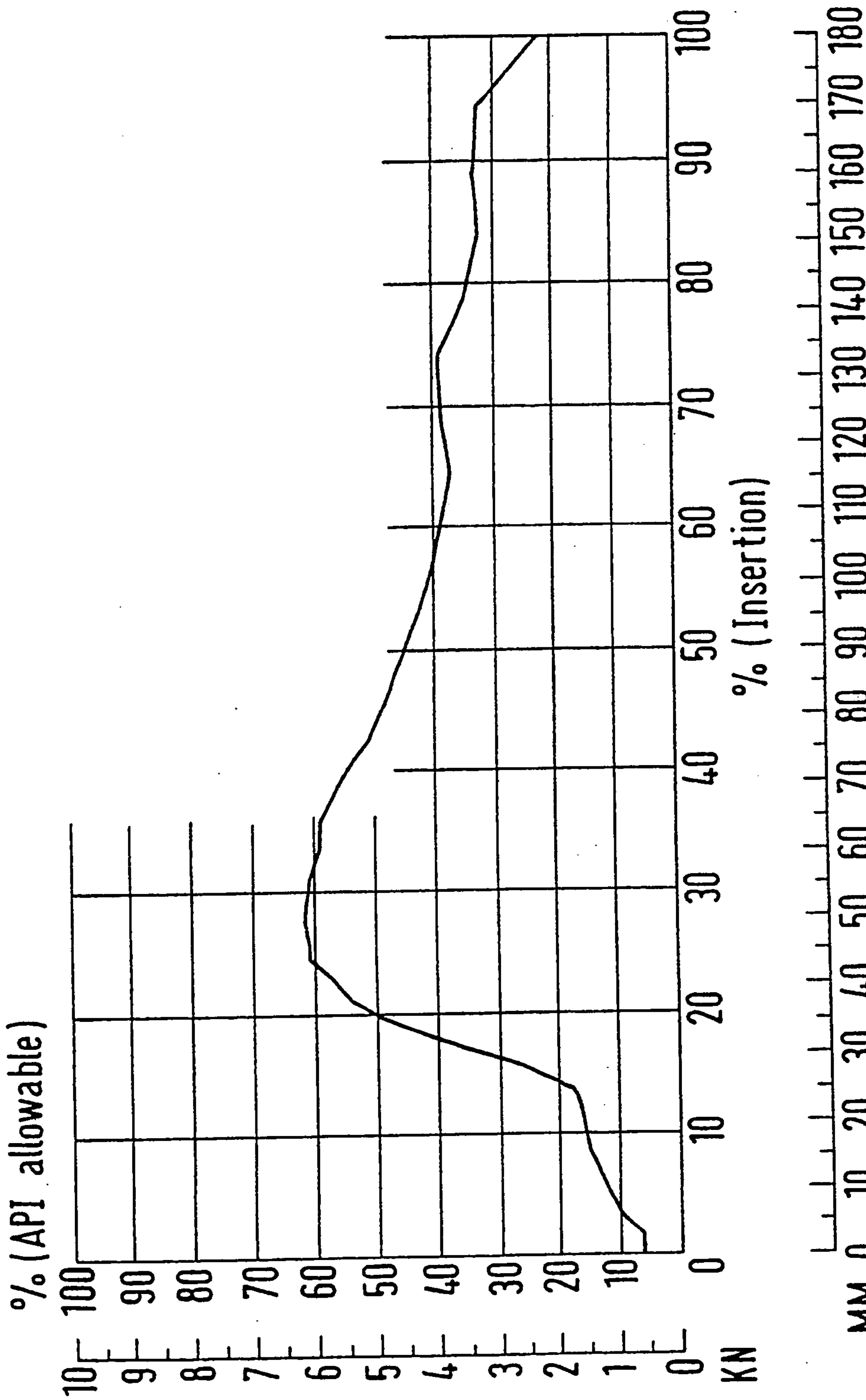


FIG.14

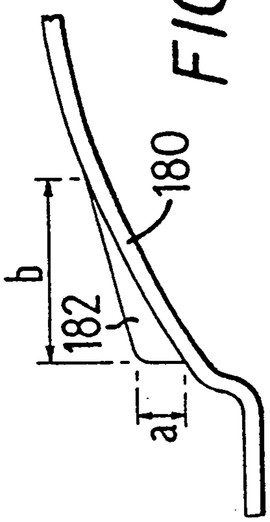


FIG.14a

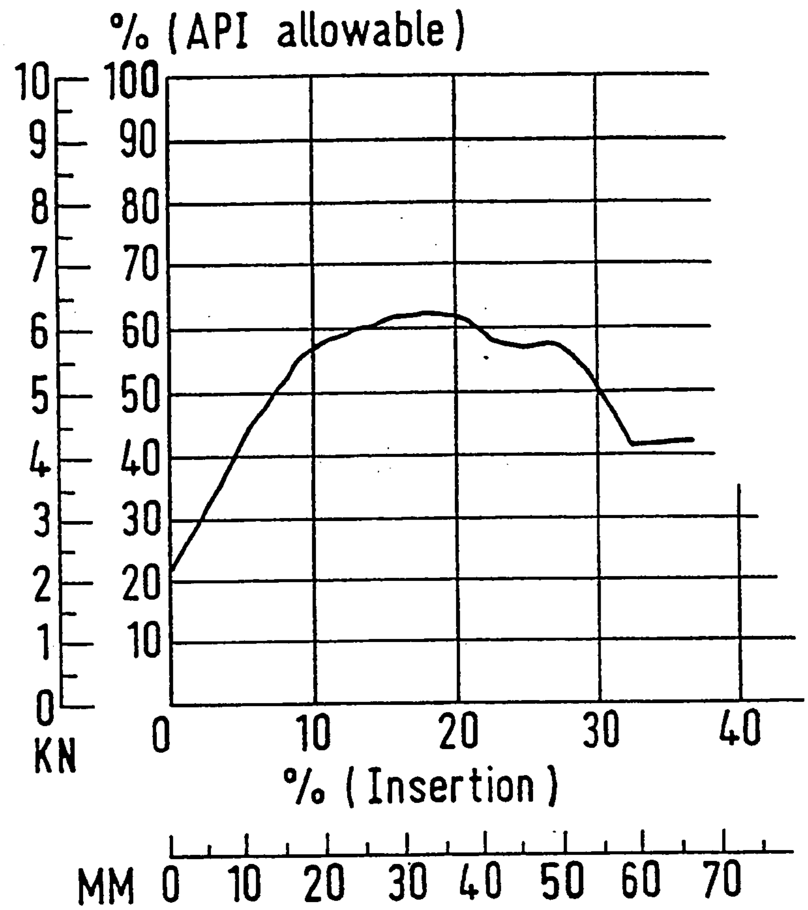


FIG.15

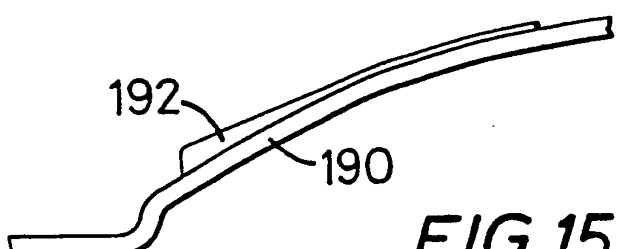


FIG.15a

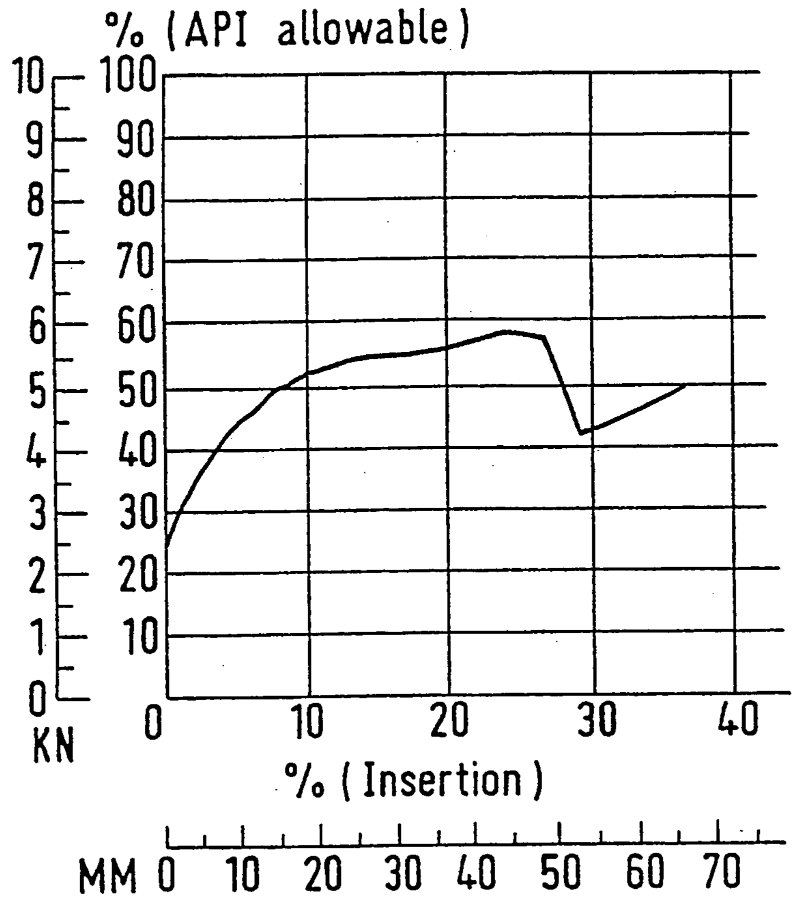


FIG. 16

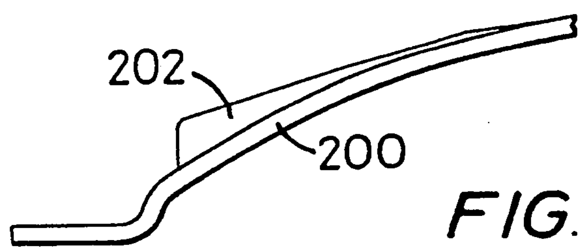


FIG. 16a

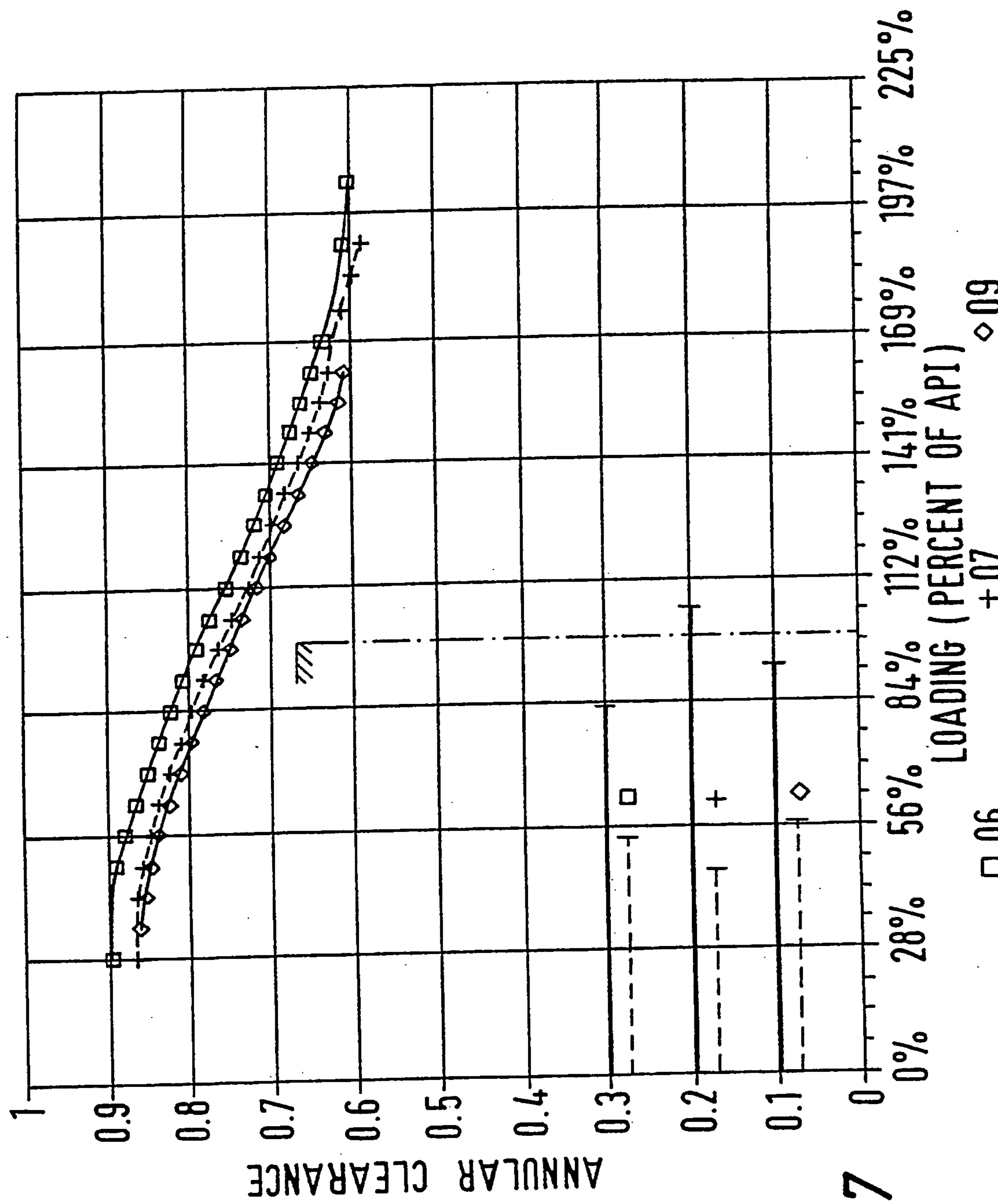
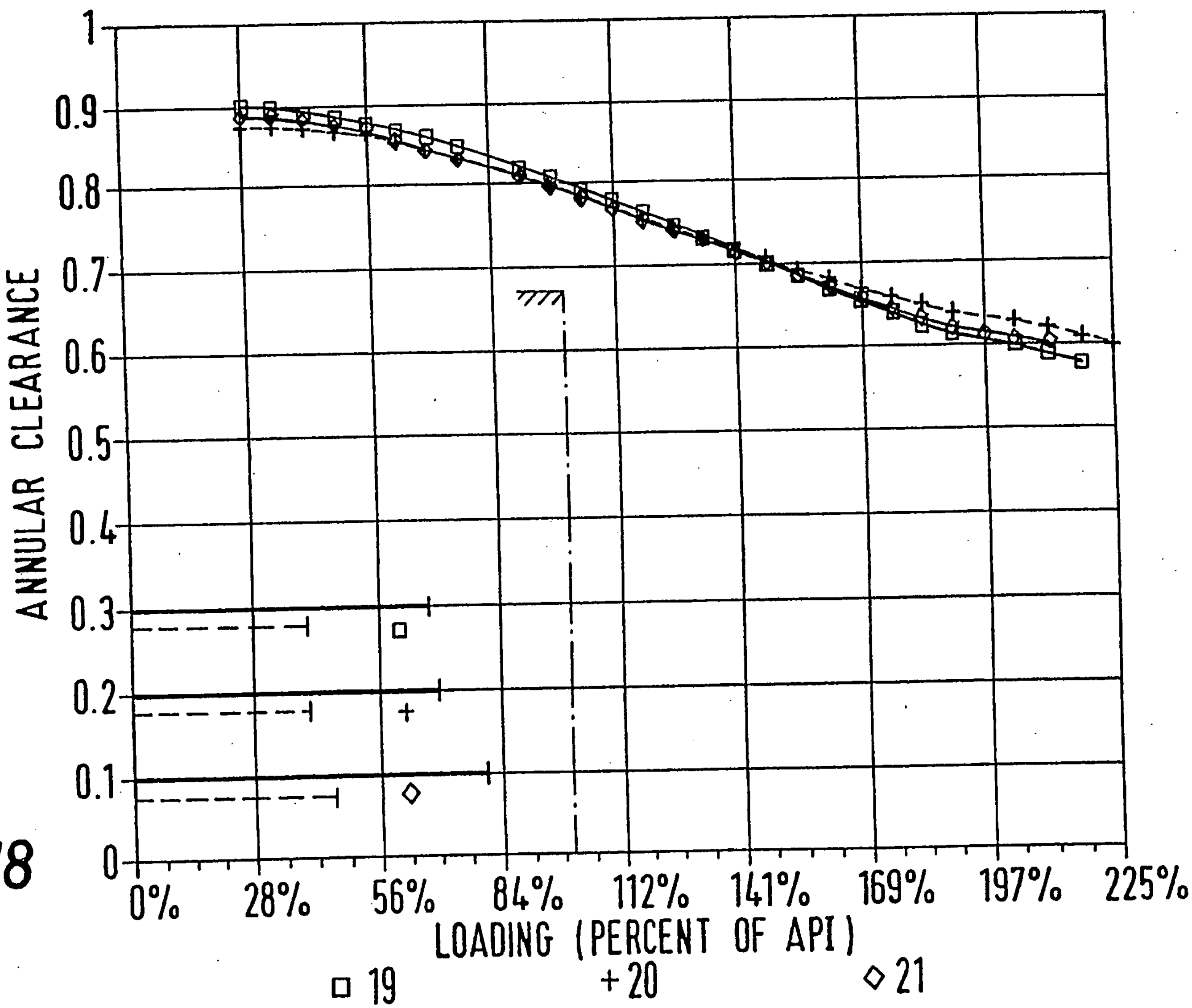

ANNULAR CLEARANCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0%
28%
56%
84%
112%
141%
169%
197%
225%
LOADING (PERCENT OF API)
□ 06
+ 07
◇ 09

FIG.17


ANNULAR CLEARANCE
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0.9
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0.3
0.2
0.1
0
0%
28%
56%
84%
112%
141%
169%
197%
225%
LOADING (PERCENT OF API)
□ 19
+ 20
◇ 21

FIG.18

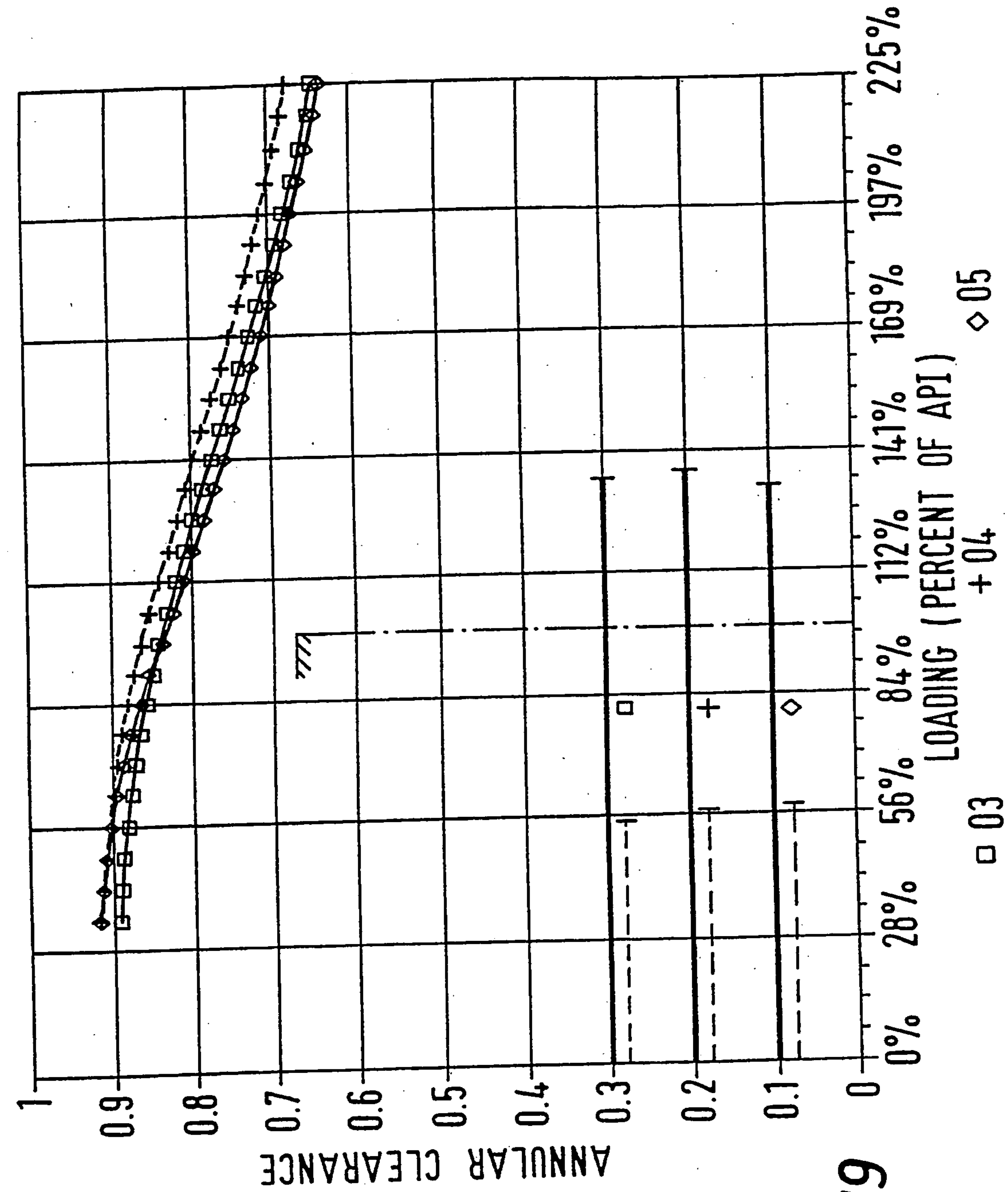

ANNULAR CLEARANCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0%
28%
56%
84%
112%
141%
169%
197%
225%
LOADING (PERCENT OF API)
□ 03
+ 04
◇ 05

FIG.19

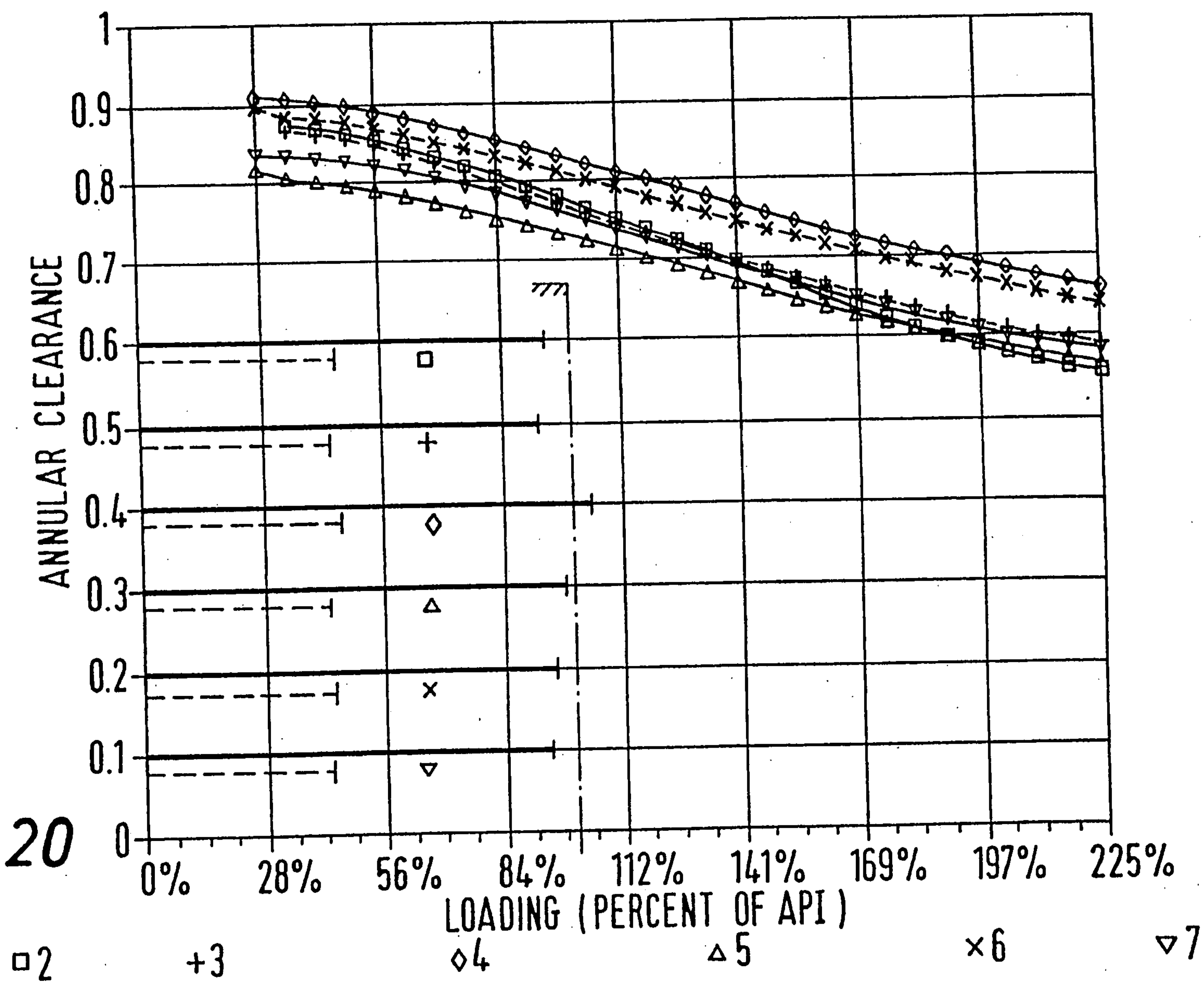

ANNULAR CLEARANCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0%
28%
56%
84%
112%
141%
169%
197%
225%
LOADING (PERCENT OF API)
□2
+3
◇4
△5
×6
▽7

FIG. 20

FIG. 21

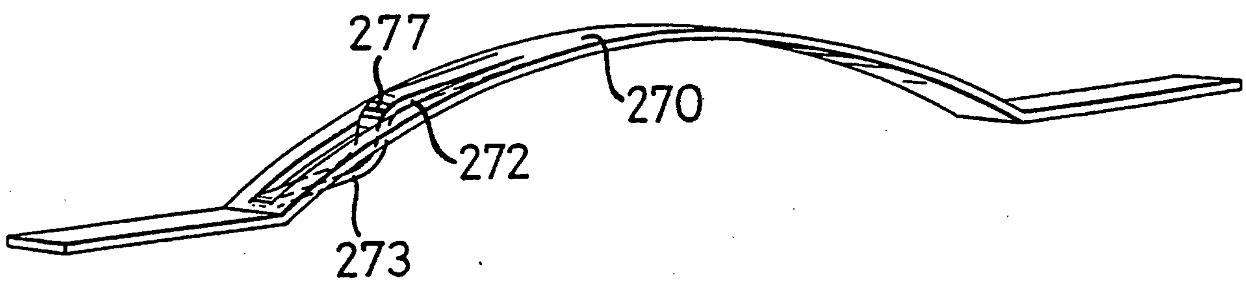
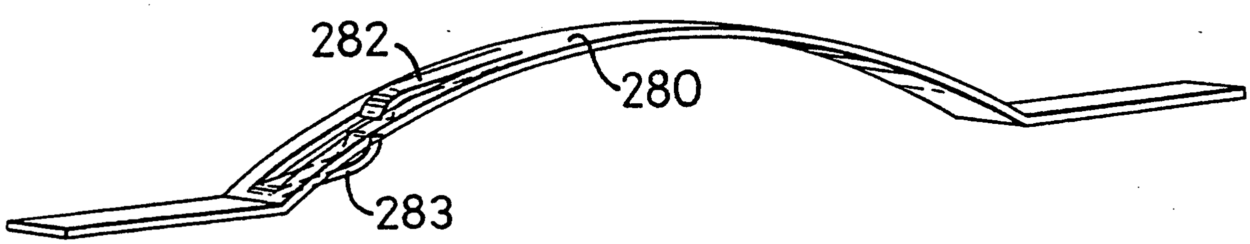


FIG. 22



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 30 4630

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A,D	US-A-3 566 965 (J.R. SOLUM) * Column 5, lines 22-34 *	1,3,5,7,8	E 21 B 17/10
A	US-A-3 749 168 (J.A. HALL) * Column 3, lines 23-27 *	1,3,7,8	
A	US-A-3 343 608 (J.R. SOLUM) * Whole document *	1,3-5,7,8	
A	US-A-2 728 399 (L. KLUCK) * Column 2, lines 16-21 *	1,4,7,8	
A	US-A-3 556 042 (W.N. LAUGHLIN) * Figure 3; column 3, lines 35-41 *	1,2,4,7,8	
A	US-A-2 656 890 (A.R. BRANDON) * Figure 2; column 3, lines 45-61 *	1,3,7,8	
A	GB-A-2 179 079 (WILLIAM HUNT ENGINEERS LTD) * Whole document *	1,2,4,6-8	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A,D	US-A-4 531 582 (J.F. MUSE) * Figures 3,4 *	1,3,4,7,8	E 21 B
A,D	US-A-2 665 762 (W.S. ALTHOUSE)		
A,D	DE-C-3 508 086 (WEATHERFORD OIL TOOL GmbH)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14-09-1988	SOGNO M.G.

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons

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